Automated radon radiometers of RRA family (*)(**)

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Summary. — We present two automated radiometers of RRA family designed for radon concentration measurements. Measurements are based on the method of electrostatic precipitation of charged radon decay daughters onto the surface of the passivated semiconductive Si(Au) α-particle detector. Radon ^{222}Rn and thoron ^{220}Rn concentrations are determined from the quantity of registered α-particles at RaA (^{218}Po) and TnA (^{216}Po) decays. Radon concentration, temperature, relative humidity and pressure are measured simultaneously so that radon concentration can be followed with time and correlation dependences between the parameters can be obtained. Principal performance specifications and promising applications of the radiometers are presented.

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1. – Introduction

Currently the problems of radon monitoring are of top-priority in the majority of developed countries.

More than 70% of all efforts in the field of radiation hygiene and radiation protection are devoted just to this problem. Researches are conducted in two key directions:

– detection of areas and buildings with excess radon concentration in air and elaboration of recommendations on reducing a radiation dose of people living inside such buildings;

– study of radon effect as a possible cause of cancer by the methods of epidemiological and experimental researches.

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To solve the above problems, it is essential to have both devices for measurements of the annual-average equivalent equilibrium volume radon activity (integral instrumentation) and survey devices for express measurements.

Following is the description of devices based on the same measurement mode which are applicable to a solution of the problems.

2. – "Alpharad" radiometer

The first radiometer named "Alpharad" has been designed and produced serially by the specialists of the MphEI faculty of theoretical and experimental physics. The device has been developed as a monitoring gauge in the course of work on the International Science Technology Center's (ISTC) project #484 "Modular multifunctional automated system for environmental monitoring". The radiometer (see fig. 1 and table I) is designed to perform sanitary-ecological indoor monitoring of radon concentration (RC). For active sampling into the measuring chamber, the radiometer is equipped with a micro air-pump with a pumpage of 1-2 l/min.

Measurements are based on the method of electrostatic precipitation: charged radon decay daughters (RDD) are precipitated in the sensitive volume of the measuring chamber onto the surface of the passivated semiconductive Si(Au) α-particle detector (SCD) with an effective area of 100 mm^2.

Detector's passivation is necessary for protecting the sensitive surface of the detector mainly against water. Such detector can be cleaned by various alcohol solutions. SCD has been preferred because of its high resolution. Such a resolution allows to easily identify peaks corresponding to the radon decay daughters (RaA (^{218}Po) $E_\alpha = 5.998$ MeV, $T_{1/2} = 3.05$ min, RaC′ (^{214}Po) $E_\alpha = 7.684$ MeV, $T_{1/2} = 1.6410^{-4}$ s and TnA (^{216} Po) $E_\alpha = 6.4$ MeV, $T_{1/2} = 55$ s) by a spectrometer (fig. 2).

For RDD precipitation, the high positive voltage is applied to a mesh positioned all around the measuring chamber (fig. 3). Optimal high voltage on the mesh is determined by geometry of the measuring chamber and, in the instant case, is taken as 1400 V. An analog unit consists of a high-voltage supply unit and a charge-sensitive pre-amplifier. A micro-processor produced by the Phillips Semiconductors firm controls measurements, analysis and data acquisition. A timer built in a digital unit and

Fig. 1. – Appearance of "Alpharad" radiometer.

TABLE I. – *Principal performance specifications of the "Alpharad" radiometer.*

Radon-222 concentration measurement range, $Bq \cdot m^{-3}$	$20–2.0 \cdot 10^4$
Limit of main admissible relative error, %	
– in sub-range from 20 up to 100 $Bq \cdot m^{-3}$	30
– in sub-range from 100 up to $2.0 \cdot 10^4$ $Bq \cdot m^{-3}$	20
Measurement time, minutes	20
Amount of RAM-stored data sets	more than 1500
Range of temperature measurement, °C	+ 5–+ 40
Range of humidity measurement, %	30–100
Range of pressure measurement, gPa	850–1100
Inaccuracy of pressure, temperature and humidity measurements, %	less than 10
Operation in portable mode (battery-powered), h	65
Weight with batteries no more than, kg	4.5
Dimensions, mm	240(H) × 160(W) × 280(L)

a Li-battery allow to correlate the data with absolute time of measuring, to monitor the battery state, to save the stored data over a period of 3 years even after discharging and replacement of the batteries.

Radon ^{222}Rn and thoron ^{220}Rn concentrations are determined from the quantity of registered α-particles at RaA (^{218}Po) and TnA (^{216}Po) decays. Electric pulses produced by α-particles' impinging on the SCD effective surface are amplified by a charge-sensitive pre-amplifier and transmitted to an amplitude-digital converter (ADC) for further processing. The effect caused by RaA deposition on the detector

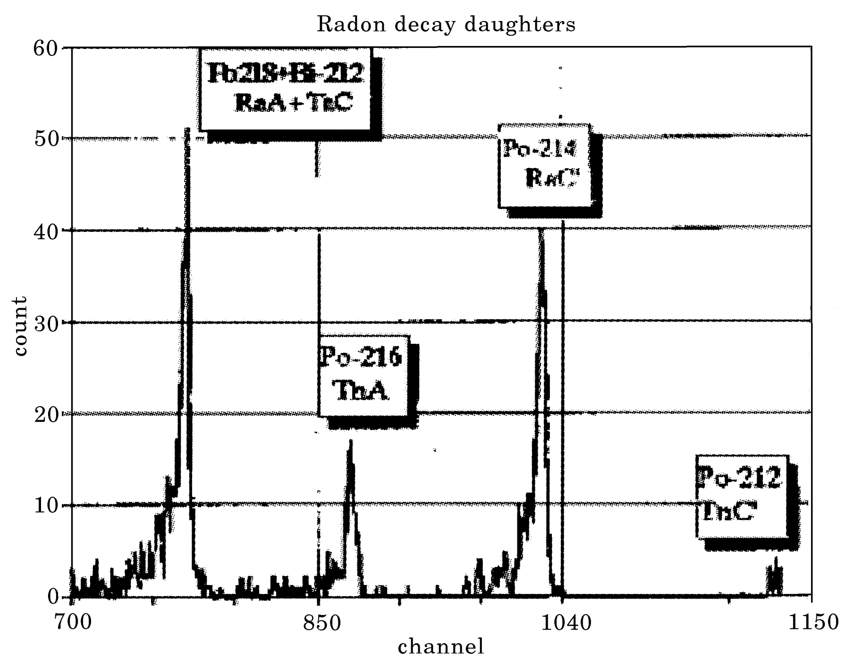

Fig. 2. – Real α-spectrum of radon decay daughters' mixture (information output from the radiometer to a multi-channel analyzer).

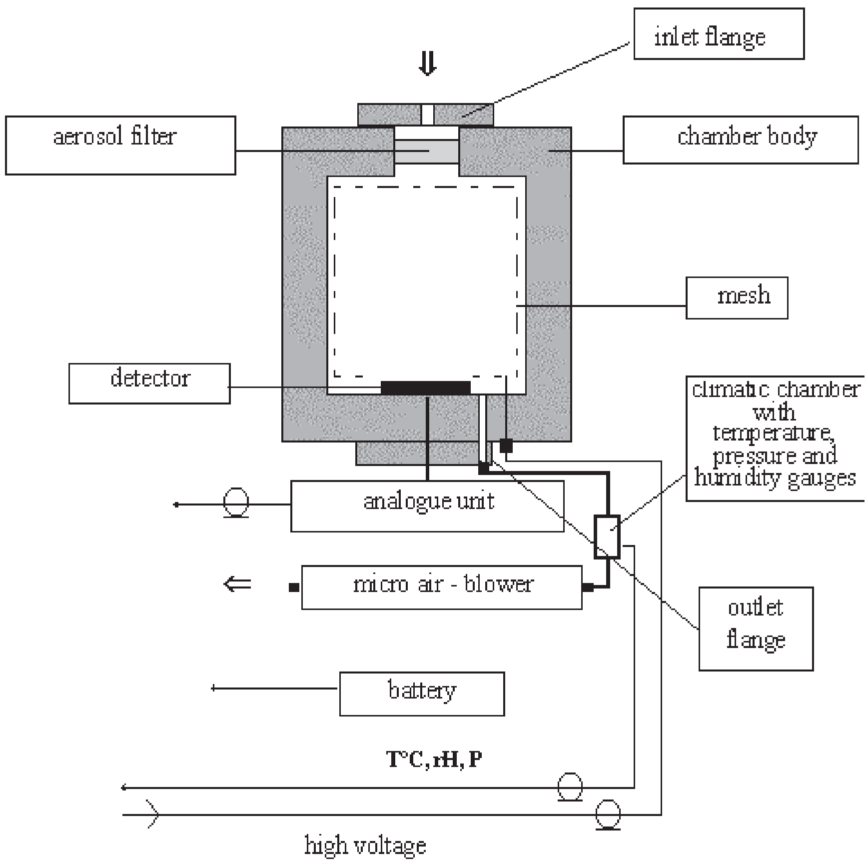

Fig. 3. – Scheme of a detecting unit.

surface does not impact on the result of following measurements due to RaA and TnA short half-lives, as well as due to the special background-compensating program stored in the radiometer internal memory. When RC decreases from 5000 to 20 $\mathrm{Bq \cdot m^{-3}}$ the radiometer enters to the background operating mode for 50 minutes. The final result of RC measurement is available in 3 minutes after beginning the measurement. The results are corrected every other minute. Spectrometric and digital monitoring information is input to PC through RS232 interface, further graphic presentation and print-out are available. Analogue output from the radiometer's pre-amplifier to a multi-channel analyzer is also available. The radiometer operates on both main power supplies (50 Hz, 220 V) and batteries.

Petryanov aerosol filters АФА РСП-20 with $CaCl_2$ drier are mounted on the inlet flange. SCD is arranged at the center of the outlet flange. The filter protects the measuring chamber against water, dust and already existing RDD. The measuring chamber is produced from materials which allow to support a constant radiometer sensitivity at a relative humidity up to 86%. Simultaneous measuring of RC, temperature, relative humidity and pressure by the radiometer allows to follow the

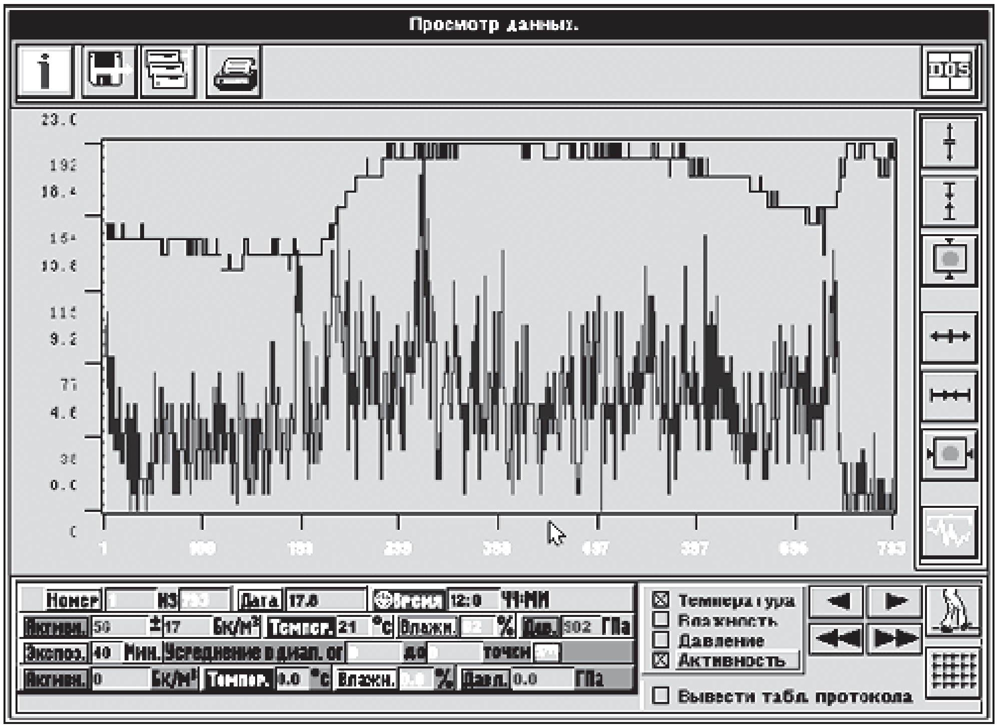

Fig. 4. – Example of monitoring RC and temperature with time.

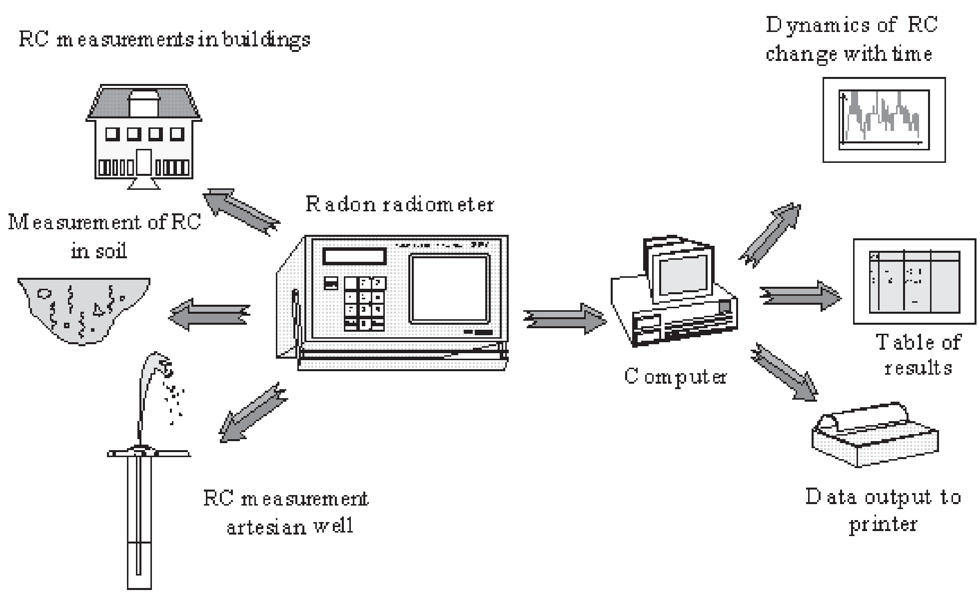

Fig. 5. – Radiometer applications.

TABLE II. – *Principal performance specifications of the SER-01 radiometer.*

Radon-222 concentration measurement range, $Bq \cdot m^{-3}$	$2–6.5 \cdot 10^4$
Exposure duration	1 minute up to 0.5 year
Amount of RAM-stored data sets	more than 8000
Operation in portable mode (battery-powered), H	720
Weight with batteries no more than, kg	1.5
Dimensions, mm	90(H) × 130(W) × 180(L)

dynamics of RC changing with time and to obtain correlation dependences between these parameters (fig. 4).

The device with additional attachments and by convenient methods allows to measure RC in soil [1] and water *in situ* [2] (fig. 5).

3. – **Radon radiometer** SER-01

The second radon radiometer SER-01 of RRA family is intended for radon concentration measurements, indication and warning (see fig. 6 and table II). It has been designed as a wall modification for long-term RC indoor monitoring. Passive radon diffusion into a small electrostatic measuring chamber through an aerosol filter has been taken as sampling. There are several similar foreign models of passive portable radiometers (for example, the professional radon monitor "Honeywell" designed by the Victoreen firm). SER-01 allows to measure integral annual and current RC values.

Fig. 6. – SER-01 appearance.

The digital display displays the results immediately. Three levels of radon concentration warning are provided. The radiometer allows to input data to the IBM PC, to represent them graphically and in the form of a measurement report, to carry out setting a date and reading a number and sensitivity of a device from IBM, to interrupt and proceed measurements. The device self-testing with visual indication of malfunctions is provided.

Exposure duration is variable and is selected automatically from the RC value. Figure 7 illustrates the results of RC monitoring conducted by the Metrological Institute of the Czech Republic [3].

4. – Conclusions

It has been shown that various problems of radon concentration monitoring in various mediums (air, water, soil) can be solved with the help of two base devices and their attachments and apparatuses. It is clear that, being connected in well-known circuit, the first radiometer is applicable to measurements of emanating power of construction materials. By now, the method of measurement of radon exhalation from soil based the on "Alpharad" radiometer has found wide acceptance in Russia.

By applying the corresponding methodology [4] and modifying the radiometer design, it is also possible to solve problems of hazard assessment in generation of rock burst or earthquakes.

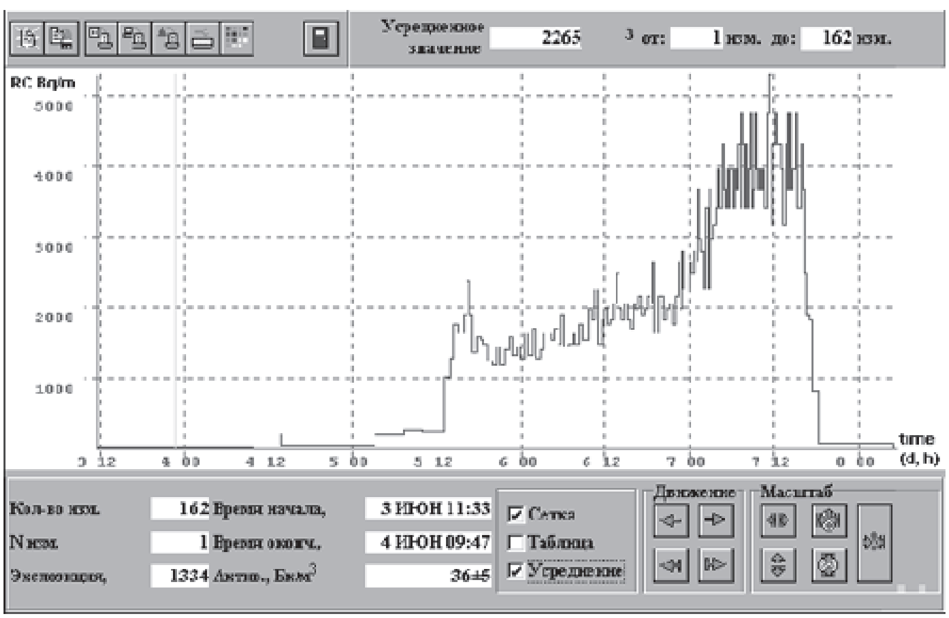

Fig. 7. – Monitoring of RC with time in radon chamber.

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